PB87-166245

Overview of Hazardous/Toxic Waste Incineration

(U.S.) Environmental Protection Agency
Cincinnati, OH

Jun 86

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. PB87-166245
EPA/600/J-86/281		

4. TITLE AND SUBTITLE	5. REPORT DATE
An Overview of Hazardous/Toxic Waste Incineration (Journal Version)	1986
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
C.C. Lee, George L. Huffman and Donald A. Oberacker	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
USEPA, HWERL 26 W. St. Clair St., Cinti. OH 45268	11. CONTRACT/GRANT NO. In-house
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
USEPA, HWERL 26 W. St. Clair St., Cinti. OH 45268	March, 1986 - June, 1986
	14. SPONSORING AGENCY CODE EPA/600-12

15. SUPPLEMENTARY NOTES

REF: J. Air Poll. Control Assoc., 36(8):922-931, August 1986

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Resource Conservation and Recovery Act, incineration, hazardous waste, toxic waste incinerator, destruction and removal efficiency, principal organic hazardous constituents, products of incomplete combustion, air/fuel ratio, air pollution control devices		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	11
	20. SECURITY CLASS (This page)	22. PRICE
	UNCLASSIFIED	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS [illegible]

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

EPA/600/J-86/281
JOURNAL ARTICLE

HAZARDOUS WASTE MANAGEMENT

An Overview of

Hazardous/Toxic Waste Incineration

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Effective hazardous/toxic waste disposal and safe dumpsite cleanup are two of EPA's major missions in the 1980s. Incineration has been recognized as a very efficient process to destroy the hazardous wastes generated by industry or by the dumpsite remediations. This paper provides an incineration summary ranging from discussion of broad regulatory and permitting requirements through more detailed descriptions of typical incineration processes and monitoring techniques.

It is estimated that over 264 million metric tons of organic hazardous/toxic wastes is generated annually in the United States, posing a serious threat to human health and the environment if improperly managed.[1] The federal government responded to the critical hazardous waste problem with the enactment of the Resource Conservation and Recovery Act (RCRA) in 1976 (Public Law 94-580), the Toxic Substance Control Act (TSCA) in 1976 (Public Law 94–469), and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in 1980 (Public Law 96–510) to assure the reliable management of hazardous/toxic waste disposal operations and dumpsite cleanup. The enactment of these laws has intensified research into the thermal destruction of organic chemical waste and this research has accumulated a large amount of useful information.

Incineration (or "thermal destruction") has been well recognized as one of the best demonstrated and available technologies for waste destruction. Incineration is an engineered process, with waste destruction being the ultimate goal. Its function is to use either direct or indirect heat to break chemical structures of organic compounds, thus reducing the volume and toxicity of the remaining residuals.

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From an engineering viewpoint, the basic objective of the incineration process is to efficiently combust the material to an ash that is acceptable for land disposal while assuring that the exhaust gas products can likewise be dispersed without harm to the environment. Secondary objectives are to carry out the process with minimum energy usage and minimum system maintenance costs.

This paper provides an overview of hazardous/toxic waste incineration. It is intended for those who are not involved in actual incineration management or operations, to enable them to easily understand the status of and the prospects for incineration. It describes current regulatory requirements and provides an overview of hazardous waste incineration. Data on the performance of and emission levels associated with incinerators are not provided in this paper because they have been made available in other recent EPA publications.[2–5]

The Regulatory Basis for Incineration

RCRA and TSCA are two key pieces of legislation enabling EPA to regulate wastes generated from either industrial processes or from CERCLA's dumpsite cleanup activities. In general, RCRA covers all hazardous wastes except for PCB (which is considered a toxic substance and is regulated under TSCA).

RCRA Requirements

In 1980, EPA published a comprehensive list of hazardous wastes.[6–8] The next year (1981), under RCRA, EPA promulgated the standards for operating hazardous waste incinerators.[9] The key requirements of the standards are:

- An incinerator must achieve a destruction and removal efficiency (DRE) of 99.99 percent for each principal organic hazardous constituent (POHC) designated for each waste feed. Initially, EPA suggested the use of compound incinerability and concentration for selecting POHCs. It further suggested that heat of combustion (ΔH_c) be used as the measure of compound incinerability in its guidance manual to permit writers.[10]
- DRE for an incinerator/air pollution control system is defined by the following formula:

$$\text{DRE} = \frac{W_{in} - W_{out}}{W_{in}} \times 100$$

where DRE = destruction and removal efficiency, percent
W_{in} = mass feed rate of POHC to the incinerator
W_{out} = mass emission rate of POHC to the atmosphere (as measured in the stack prior to discharge)

- An incinerator burning hazardous waste containing more than 0.5 percent chlorine must remove 99 percent of the hydrogen chloride from the exhaust gas.

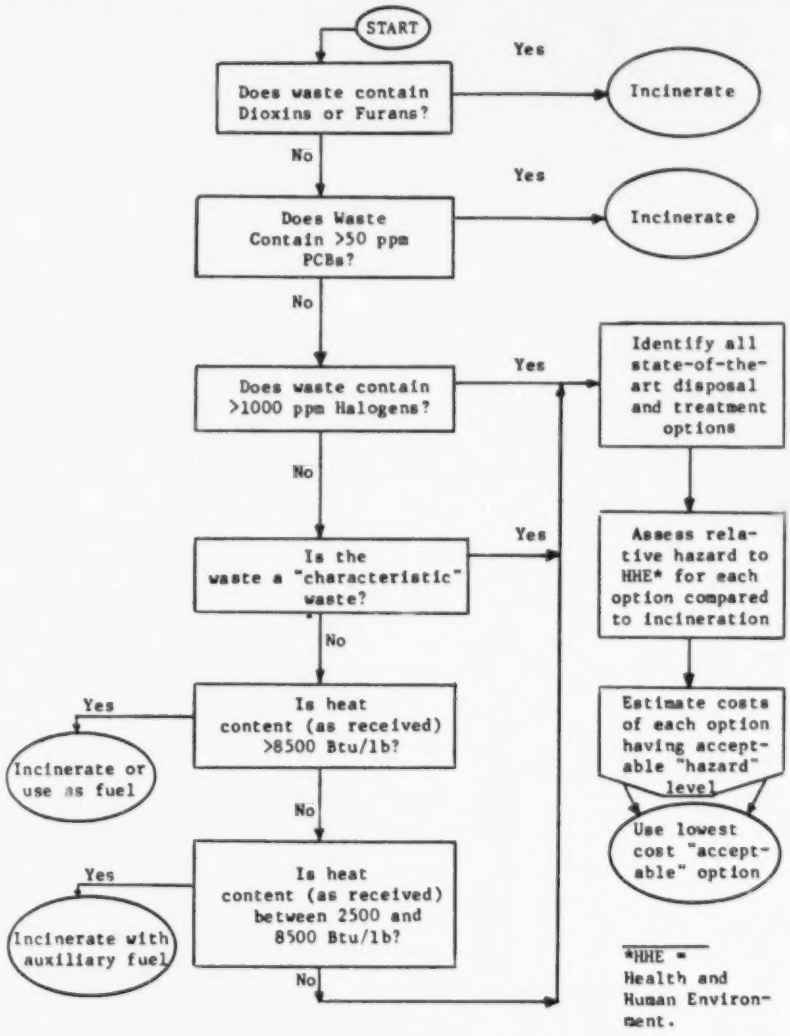

Figure 1. Conceptual strategy for determining waste burnability.

- An incinerator burning hazardous waste must not emit particulate matter exceeding 180 mg/dscm corrected to 7 percent O_2 in the stack gas.

A trial burn (or data equivalent to a trial burn) is generally required to demonstrate the ability of a hazardous waste incinerator to comply with the above performance standards.

TSCA Requirements

In 1979, under TSCA, EPA promulgated the standards for operating PCB (polychlorinated biphenyl) incinerators. The general requirements of the standards are: [11]

- Liquid PCBs—maintenance of the introduced liquids for a 2-second dwell time at 1200°C (± 100°C) and 3 percent excess oxygen in the stack gas; or
- Maintenance of the introduced liquids for 1.5- second dwell time at 1600°C (± 100°C) and 2 percent excess oxygen in the stack gas.
- Combustion efficiency shall be at least 99.9 percent computed as follows:

$$\text{Combustion efficiency} = [C_{CO_2}/(C_{CO_2} + C_{CO})] \times 100$$

where C_{CO_2} = concentration of carbon dioxide
C_{CO} = concentration of carbon monoxide

- Nonliquid PCBs—the mass of emissions from the incinerator shall be no greater than 0.001g PCB/kg of the PCB introduced into the incinerator. (This is equivalent to 99.9999 percent DRE.)
- Similar to the RCRA requirements, a trial burn is generally required to demonstrate that the incinerator meets the above standards.

Wastes Suitable for Incineration

Background information about the hazardous waste to be burned is generally available. Such information may have been generated under RCRA's Section 3001 (Identification and Listing of Hazardous Waste), Section 3002 (Standards Applicable to Generators of Hazardous Waste), or Section 3003 (Standards Applicable to Transporters of Hazardous Waste) of the RCRA regulations. Additional information usually can be obtained from studies of the process(es) generating the waste(s). This background information is helpful in evaluating waste for incineration.

Factors to be considered in evaluating waste for incineration are:

- Dioxin/furan and PCB content
- Moisture content
- Potential pollutants expected in incinerator effluents
- Inert (ash) content
- Heating value and auxiliary fuel requirements
- Potential health and environmental effects of the effluents
- Physical form
- Corrosiveness
- Known carcinogenic content

A conceptual strategy for determining the wastes which are candidates for thermal destruction is shown schematically in Figure 1.[12] In general, the heat content of the waste burned must maintain adequate ignition and incineration temperatures or a supplemental fuel must be provided.

The Incineration Concept

Conventional speculation suggests that about 99 percent of wastes are destroyed in the flame zone of an incinerator, and that about 1 percent is destroyed in the post-flame zone. From a chemical point of view, incineration is an intensive oxidation process. Incineration or combustion basically refers to the rapid oxidation of organic substances. When oxidation is rapid, the temperature of the material rises rapidly due to the inability of transferring heat to the surroundings as rapidly as it is produced by the oxidation reaction. As a result, the material emits visible radiation which is referred to as a "flame." A simplication of the overall

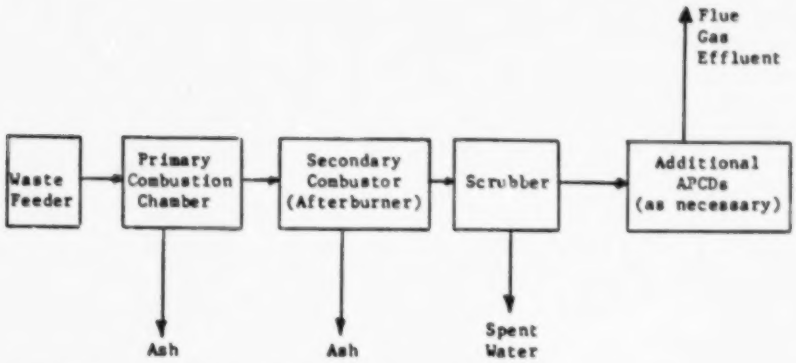

Figure 2. Key components of a typical incineration system.

chemical process that takes place during incineration is as follows:

Reactants		*Products*	
$C + O_2$	→	CO_2	(1)
$H_2 + \frac{1}{2}O_2$	→	H_2O	(2)

In actuality, these reactions (and the three that follow) seldom go to 100 percent completion. Consequently, numerous products of incomplete combustion (PICs) can, and oftentimes do, form—generally, however, in the ppm range.

There are three major components in a combustion system: fuel, oxidant, and diluents. A fuel containing energy-rich bonds such as carbon-carbon, carbon-hydrogen, and hydrogen-hydrogen bonds is a common source of chemical potential energy. During combustion, such fuels are oxidized and their chemical potential is transformed into thermal energy. The second distinct component of a combustion system is the oxidant. The oxidant reacts with the fuel during combustion to release the chemical potential energy stored in the fuel as thermal energy. Most commonly, the oxidant is molecular oxygen, a constituent of combustion air. The third component is the diluent. A diluent in this discussion is a substance that does not participate chemically in the combustion reaction either as a fuel substance or as an oxidant. It is physically present and often does influence the combustion process. For example, nitrogen is a diluent which has heat capacity and, while it does not make a positive contribution to the total energy released, it acts as a thermal sink and limits the temperature rise achieved by combustion. One unit of oxygen has 3.76 units of nitrogen in combustion air. Therefore, for example, propane (C_3H_8) combustion at 100 percent of theoretical air can be expressed as follows:

For 100 percent theoretical air

$$C_3H_8 + 5(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 18.8N_2 \quad (3)$$

There are three types of combustion, theoretical (stoichiometric), lean, and rich combustion, depending on the quantities of oxidant available in the system. Theoretical combustion refers to the system in which the quantity of oxidant present is just sufficient to completely oxidize the fuel. Lean combustion refers to the system which contains excess oxidant, and the converse case where there is insufficient oxidant for complete oxidation of the available fuel is referred to as rich combustion.

Equation 3 above shows "theoretical combustion," Equation 4 below shows lean combustion and Equation 5 depicts rich combustion.

For 80 percent of theoretical air (rich combustion)

$$C_3H_8 + 5 \times 0.8(O_2 + 3.76N_2) \rightarrow 2CO + CO_24H_2O + 4H_2O + 15.04N_2 \quad (4)$$

For 150 percent of theoretical air (lean combustion)

$$C_3H_8 + 5 \times 1.5(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 2.5O_2 + 28.2N_2 \quad (5)$$

Combustion is a very complicated process. It involves complex interaction of heat and mass transfer, and chemical kinetics in a two-phase system. It is so complicated that many consider it as an art rather than a science. Applying already-complicated combustion theories to hazardous waste incineration makes the problem even tougher. The ultimate goal of hazardous waste incineration is to convert the hazardous materials into harmless combustion products (such as CO_2 and H_2O) which can be rejected directly to the atmosphere or removed by air pollution control devices when the combustion products are not totally harmless in themselves.

Table I. Estimation of available incinerator capacity by incinerator design.

Incinerator design	Number of units	Average design capacity (MM Btu/h)	Utilization (percent)	Available capacity (MM Btu/h)	Percent with air pollution control equipment
Rotary kiln	42	58.7	77	570	90
Liquid injection	95	36.1	55	1840	42
Fume	25	29.5	94	40	40
Hearth	32	22.5	62	270	38
Other	14	23.8	—	110	—
Total or average values	208	37.6[a]	67[b]	2530	50

[a] 181 incinerators reporting.
[b] 90 incinerators reporting.

Description of Major Incineration Processes

In general, the key components and their configuration in a "typical" incinerator system are shown in Figure 2.

Waste Feeders

The type of waste feeder employed depends entirely on the characteristics of the wastes to be incinerated. The factors that need to be considered in selecting a proper waste feeder include:

- Waste physical form: solid, liquid, gas or mixture
- Solids: size, form, and quantity
- Liquids: viscosity as a function of temperature, and specific gravity
- Sludges (slurries): density, viscosity and percent solids
- Gases: density
- Special characteristics: toxicity, corrosiveness, and other unusual features.
- Disposal rate: peak, average, and

Table II. Applicability of available incineration processes to the burning of waste (by waste type).

Waste type	Rotary kiln	Liquid injection	Fluidized bed[a]	Fixed hearth (controlled air)
Solids:				
Granular, homogeneous	X		X	X
Irregular, bulky (pellets, etc.)	X			X[b]
High melting point (tars, etc.)	X	X[c]	X	X
Organic compounds with fusible ash constituents	X			X
Unprepared, large, bulky material	X			
Gases:				
Organic vapor-laden	X[d]	X[d]	X[d]	X[d]
Liquids:				
High organic-strength aqueous wastes often toxic	X[e]	X	X	
Organic liquids	X[e]	X	X	
Solids/liquids:				
Waste contains halogenated aromatic compounds	X	X[f]		
Aqueous organic sludge	X[g]		X	

[a] Suitable for pyrolysis operation.
[b] Handles large material on a limited basis.
[c] If material can be melted and pumped.
[d] If properly fed into the incinerator.
[e] If equipped with auxiliary liquid injection nozzles.
[f] If liquid.
[g] Provided waste does not become sticky upon drying.

minimum at the present and future requirement levels.

For example, liquid feeder systems consist of waste filtration, waste/fuel blending and feed preheating (optional) while solid feeders are designed to feed waste pneumatically, mechanically or by gravity to the incinerator.

Primary and Secondary Combustors

The primary combustor is an important part of an incinerator system. The incinerator system is usually named after the primary combustor such as "a rotary kiln incinerator" or "a liquid injection incinerator." Secondary combustors (afterburners) are simple combustion chambers (incinerators) designed to improve destruction efficiencies. As a first step to an air pollution control process, the afterburner acts to continue the combustion process and greatly decrease pollutants in the flue gas. This in turn creates less pollutant loading on downstream emission control devices which then require less servicing and maintenance, and produce less residue as a result. In general, primary combustors can be grouped into two categories: conventional incinerators and innovative thermal destructors. Only conventional incinerators will be discussed here.

In 1985, EPA conducted a survey relative to the types and population of conventional incinerators in the United States. The survey showed that three types of conventional incineration processes dominate the incineration field. They are the liquid injection, rotary kiln, and hearth processes. A summary of their features, along with those of some others, is given in Table I.[13] Table II compares the applicability of these technologies with a variety of waste types.[14]

Liquid Injection Incinerators (LIIs). Liquid injection incinerators, as the name implies, are applicable almost exclusively to pumpable liquid waste. These incinerators are usually simple, refractory-lined cylinders (either horizontally or vertically aligned) equipped with one or more waste burners. Liquid wastes are injected through the burner(s), atomized to fine droplets, and burned in suspension. Burners as well as separate waste injection nozzles may be oriented for axial, radial, or tangential firing. Improved utilization of combustion space and higher heat release rates, however, can be achieved with the utilization of swirl or vortex burners or designs involving tangential entry. A typical horizontally-fired incinerator is shown in Figure 3.[15]

Vertically-aligned liquid injection incinerators are preferred when wastes are high in inorganic salts and ash content while horizontal units may be used with low ash waste. The typical capacity of liquid injection incinerators is roughly 10×10^6 Btu/h (2.5×10^6 kcal/h). Units, however, range as high as 70 to 100×10^6 Btu/h (17.6 to 25.2×10^6 kcal/h.[14]

Advantages of LIIs

- No secondary combustion chamber is needed if the primary combustor has enough residence time—2 seconds as a general rule of thumb.
- Capable of incinerating a wide range of liquid hazardous waste.
- No continuous ash removal system is required other than for downstream air pollution control systems.
- Capable of a fairly high turndown ratio.
- Virtually no moving parts.
- Low maintenance costs.

Disadvantages of LIIs

- Only wastes which can be atomized through a burner nozzle can be incinerated.
- Burners susceptible to pluggage (burners are designed to accept a certain particle size; therefore, particle size is a critical parameter for successful operation).
- Burner may or may not be able to accept a material which dries and cakes as it passes through the nozzles.

Rotary Kiln Incinerators (RKIs). Rotary kiln incinerators are more versatile incinerators in the sense that they are applicable to the destruction of solid wastes, slurries, and containerized waste as well as liquids. The rotary kiln is a cylindrical refractory-lined shell that is mounted on a slight incline. Rotation of the kiln provides for movement of waste through the kiln as well as for enhancement of waste mixing.

To ensure complete waste combustion, rotary kiln incinerator designs normally include a secondary combustor (an afterburner). The primary function of the kiln is to convert solid waste to gases, which occurs through a series of volatilization, destructive distillation, and partial combustion reactions. However, a secondary combustor is almost always required to complete the gas-phase combustion reactions. The secondary combustor is connected directly to the discharge end of the kiln. Both the kiln and the secondary combustor are usually equipped with an auxillary fuel firing system to bring the units up to the desired operating

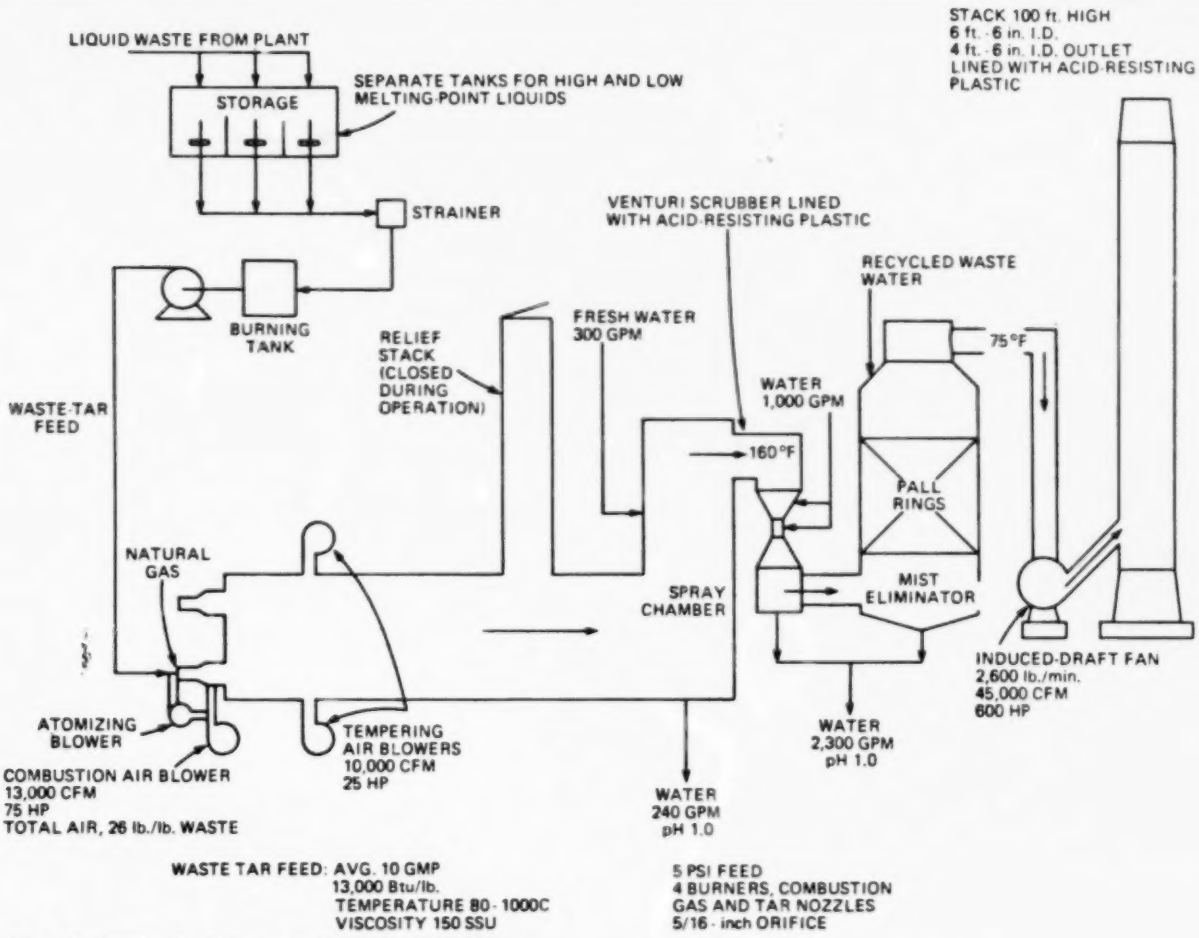

Figure 3. Example of a horizontally-fired liquid injection incinerator.

temperatures. Rotary kilns burning hazardous wastes are designed with a typical capacity of 25×10^6 Btu/h (6.3×10^6 kcal/h). A typical rotary kiln incinerator is shown in Figure 4.[15]

Advantages of RKIs[15]

- Can maintain a higher retention or residence time and incinerate a wide variety of liquid and solid hazardous wastes.
- Feed capability for drums and bulk containers.
- Continuous ash removal which does not interfere with the waste oxidation.
- The retention or residence time of the nonvolatile component can be controlled by adjusting the rotational speed.
- Rotary kilns can be operated at temperatures perhaps as high as 2,550°F (1,400°C), making them well suited for the destruction of toxic compounds that are difficult to thermally degrade.

Disadvantages of RKIs[15]

- High capital cost for installation, because of the need for the secondary combustor.
- Spherical or cylindrical items may roll through kiln before complete combustion.
- High particulate loadings.
- Problems in maintaining seals at either end of the kiln are a significant operating difficulty.
- Drying of aqueous sludge wastes or melting of some solid wastes can result in clinker or ring formation on refractory walls.

Hearth Incinerators (HIs). Hearth incinerators, also called controlled air, starved air, or pyrolytic incinerators, are the third major technology in use for hazardous waste incineration today. Hearth incineration is basically a two-stage combustion process. A cutaway view of a typical unit is shown in Figure 5.[14] Waste is ram-fed into the first stage, or primary chamber, and burned at roughly 50–80 percent of stoichiometric air requirements. This starved air condition causes most of the volatile fraction to be destroyed pyrolytically, with the required endothermic heat provided by the oxidation of the fixed carbon fraction. The resultant smoke and pyrolytic products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with products of combustion, pass to the second stage, or secondary chamber. Here, additional air is injected to complete the combustion, which can occur either spontaneously or through the addition of supplementary fuels. It is this two-stage process that generally allows low stack emissions. The primary chamber combustion reactions and turbulent velocities are maintained at such low levels by the starved air conditions that particulate entrainment and carryover is minimized. With the addition of secondary air, total excess air for controlled air incinerators is in the

100 to 200 percent range.

Secondary chambers of controlled air incinerators are generally designed to provide gas residence times from 0.5 to 1.0 seconds (0.7 seconds typically) and combustion temperatures ranging from 760°C (1400°F) to 982°C (1800°F), typically 871°C (1600°F). Longer residence times (up to 2.0 seconds) and temperatures up to 1204°C (2200°F) may be required, however, for systems burning many types of hazardous wastes.[14]

Advantages of HIs[15]

- Are well suited for sludge disposal.
- Large quantities of waste-bound water can be evaporated.
- Can utilize many types of fuels including coal dust, waste oils and solvents.
- For multizone configuration hearths, fuel efficiency is high and improves with the number of hearths used. Fuel burners can be added to any of the hearths to maintain a desired temperature profile.

Disadvantages of HIs[15]

- Need a secondary combustor, thus increasing installation, maintenance and operating costs.
- Solid wastes generally have to be pretreated prior to successful incineration.
- Not well suited for wastes containing fusible ash, wastes which require extremely high temperature for destruction of irregular bulky solids.

Air Pollution Control

Although incineration can destroy hazardous or toxic wastes, it also produces undesirable air pollutants which require that treatment procedures be adopted to ensure clean discharges of combustion gases to the atmosphere. The undesirable pollutants may include:

- Hydrogen chloride (HCl); other halogens
- Particulates
- Nitrogen oxides (NO_x)
- Sulfur oxides (SO_x)
- Products of incomplete combustion (PICs)
- Trace metals and their complexes

HCl and particulates are regulated under RCRA. Currently, there are no regulations on the emissions of PICs and trace metal (*per se*) from the operation of incinerators.

To control these undesirable pollutants, an incineration system generally requires one or more air pollution control devices (APCDs).[15] Currently, the most common APCDs used in the United States include:

APCD	*Primary control function*
Venturi scrubbers	Particulate
Packed bed scrubbers	HCl
Plate tower scrubbers	HCl
Baghouses	Particulate
Electrostatic precipitators	Particulate

The sequence of the APCD installations is likely to be as follows: Combustion gas → Quenching → Scrubber → Baghouse or ESP → Discharge.

Quenching System

The purpose of the quenching system is to reduce combustion gas temperature from about 1000°C to 100°C, a temperature which is acceptable for scrubbing operations. This lowered temperature also minimizes gas volume flow rates for downstream processing. During the quenching process, heat can be recovered if this is a desirable option.

Scrubbers

Venturi scrubbers involve the injection of a scrubbing liquid (usually water or a water/caustic solution to neutralize HCl acid gas) into the exhaust gas stream as it passes through a throat at a velocity of approximately 30 to 130 m/s. The accelerating gas creates a pressure drop at the throat and atomizes the injected liquid into fine droplets which allow a large surface area for mass transfer. It is this intimate gas/liquid contact that permits removal of the gaseous contaminants.

Contaminants are removed in packed bed scrubbers by a gas absorption process that also depends on intimate gas/liquid contact. These scrubbers are vessels filled with randomly-oriented packing material such as

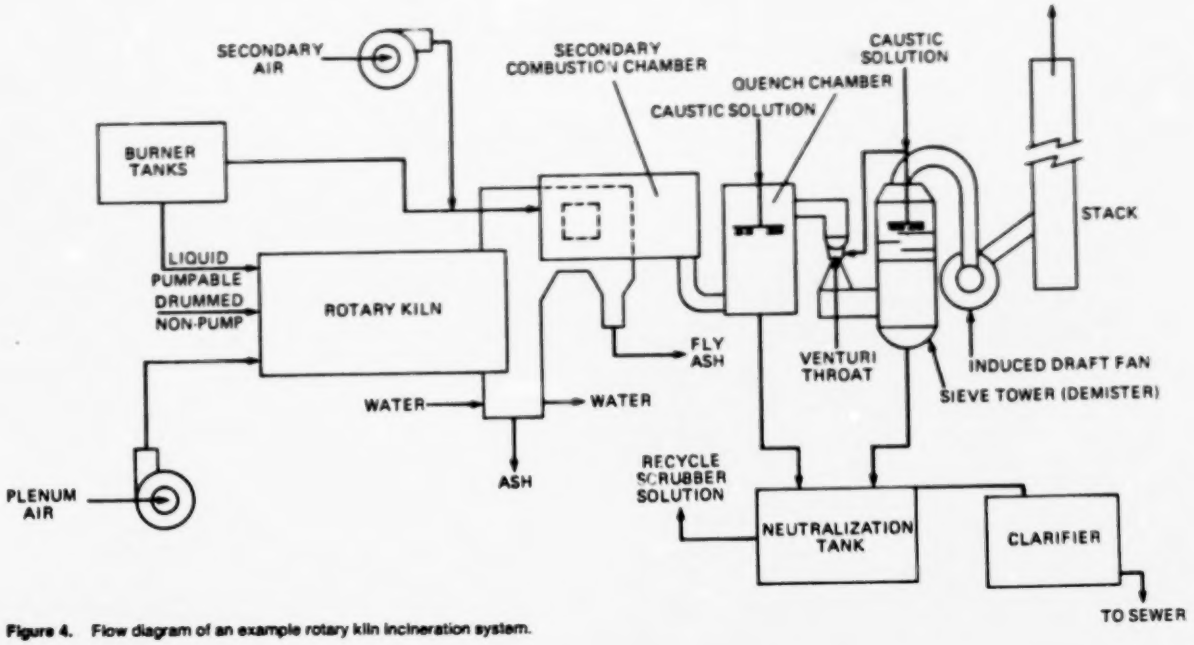

Figure 4. Flow diagram of an example rotary kiln incineration system.

Table III. Continuous monitoring parameters and methodologies.

Parameter	Method of detection
CO	Nondispersive infrared
O_2	Paramagnetic analyzer
CO_2	Nondispersive infrared
NO_x	Chemiluminescence
Total hydrocarbons	Flame ionization detection
Temperature	Thermocouple

saddles or rings. The scrubbing liquid is fed to the top of the vessel, with the gas flowing in either countercurrent, concurrent, or crossflow modes (countercurrent being the most common). As the liquid flows through the bed of packing, it wets the packing material and thus provides interfacial surface area for mass transfer with the gas phase.

Like packed bed scrubbers, plate scrubbers also rely on gas absorption into liquids for the removal of contaminants. The basic design is a vertical cylindrical column with a number of plates or trays inside. The scrubbing liquid is introduced at the top plate and flows successively across each plate as it moves downward to the liquid outlet at the tower bottom. Gas comes in at the bottom of the tower and passes upward through openings in each plate before exiting the tower at the top. Gas absorption is promoted by the breaking up of the gas phase into small bubbles which pass through the volume of liquid on each plate.[14]

Electrostatic Precipitators

Electrostatic precipitation is a process by which particles suspended in a gas are electrically charged and separated from the gas stream. In this process, negatively charged gas ions are formed between emitting and collecting electrodes by applying a sufficiently high voltage to the emitting electrodes to produce a corona discharge. Suspended particulate matter is charged as a result of bombardment by the gaseous ions and migrates toward the rounded collecting plates due to electrostatic forces. Particle charge is neutralized at the collecting electrode where subsequent removal is affected by periodically rapping or rinsing the electrode.[15]

Baghouses

A baghouse filter contains a permeable material through which a gas laden with particles is passed. The mechanisms of a baghouse filter for removing particles from a gas stream are: 1) filtration through the fibers; 2) interception: collision between the particles and the fibers of the filter media; 3) impingement: a sudden change in direction of the particle; 4) gravitational settling; 5) electrostatic attraction: for the collection of small particles; and 6) diffusion: for the collection of particles in the submicron range. All baghouse filters operate in basically the same way: Dirty gas is introduced to the unit where it is filtered by cloth tubes or bags. The filtering action usually removes greater than 99 percent of the entrained particles entering the unit.[16]

Table IV. Permit requirements for a recent New Jersey project.

Title of permit	Permit reference
Federal permits.	
Resource Conservation and Recovery Act, (RCRA)	40 CFR Parts 261, 262, 264 and 265 and 270 Treatment Storage Disposal of Hazardous Wastes
Clean Air Act	40 CFR 52.21, Prevention of Significant Air Quality Deterioration Regulation (PSD regulation)
Toxic Substances Control Act (TSCA)	40 CFR 761.40, Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions
National Environmental Policy Act (NEPA)	40 CFR Part 6, Agency Implementation of National Environmental Policy Act
National Pollutant Discharge Elimination System (NPDES)	National Pollutant Discharge Elimination System under the Clean Water Act, 33 U.S.C. 1251, Discharge of Pollutants into the Waters of the United States
State permits.	
Incinerator Permit Application for Air Pollution Control	New Jersey Department of Environmental Protection Administrative Code, Title 7, Chapter 27, Subchapter 8, Permits and Certificates
Discharge Elimination Systems Permits (NJ-PDES)	New Jersey Pollutant Discharge Elimination System 58:10 Al, et. seq.
Hazardous Waste Facility Registration Requirement Report (EIS)	Covered under New Jersey Hazardous Waste Management Regulations, 7026-1, et. seq.
Division of Hazard Management Permit (DPCC, DCR permit)	Covered under Rules Concerning Discharges of Petroleum and Other Hazardous Substances (N.J.A.C. 7.1 e-1 et. seq.; Subchapter 3 Discharge Cleanup Operations)

Monitoring Requirements

The objective of monitoring is to ensure the proper performance of incinerator operation. The state of the art is such that some parameters (such as O_2, CO_2, CO, total hydrocarbon, NO_x, temperature, etc.) can be measured on a continuous basis using automatic instruments, while some trace contaminants [such as PCB, dioxin (PCDD) and furan (PCDF)] can only be measured manually.

Continuous Emission Monitoring[17]

Instruments currently available to continuously and automatically measure their corresponding parameters are summarized in Table III. The monitoring system normally comprises a gas conditioning system for removing particulates and condensate, sensors for measuring the various parameters listed above, and a data acquisition system as shown in Figure 6.

HCl Sampling[15]

The sampling procedure developed for the determination of hydrogen chloride emissions from stationary sources is shown in Figure 7. A heated glass-lined probe is used with the temperature maintained at 300°F or at stack temperature, whichever is greater. A Pyrex wool plug is inserted in the inlet end of the probe. The impinger train, which should be immersed in an ice bath during the samping, consists of four midget impingers connected by glass U-tubes and clamps. Impinger Nos. 1 and 2 contain 15 mL of the absorbing solution (0.1N NaOH). Impinger No. 3 contains 15 mL of 3 percent H_2O_2 solution, which will remove SO_2 from the sample stream. Impinger No. 4 is a dry impinger which functions to remove moisture from the sample stream. A sampling rate of 2.0 liters per minute is typically recommended with a total sample volume of 60–300 liters (dry) per sample, depending on the expected concentrations of HCl to be measured. Samples are analyzed for chloride ion by titration with a standard solution of mercuric nitrate [$Hg(No_3)_2$].

Volatiles: Volatile Organic Sampling Train (VOST)[16]

The VOST is typically used to quantify concentrations of VOCs. VOC refers to those organic compounds with boiling points less than 150°C. The method utilizes Tenax and Tenax/charcoal cartridges to absorb the VOCs each of which is preceded by a condensing module.

The train consists of a glass-lined probe with a glass-wool plug to remove particulate, followed by an assembly of condensers and organic resin traps as illustrated in Figure 8. The first condenser cools the gas stream and condenses the water vapor present. The flue gas and condensed moisture then pass through a cartridge containing 1.5 grams of Tenax resin (60–80 mesh). The condensate is collected in the first impinger with is continually purged by a gas stream. The second condenser and trap containing Tenax/charcoal serves as a backup for low-volume breakthrough compounds. Following the second Tenax trap is a silica gel drying tube for residual moisture removal.

Semivolatiles: Modified Method 5 (MM5)[16]

Modified Method 5 sampling trains are used for the collection of particu-

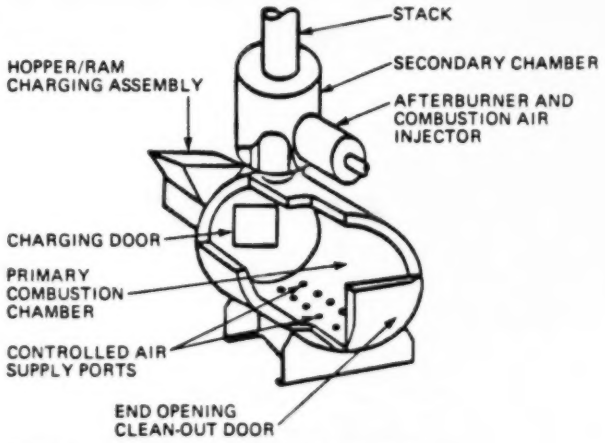

Figure 5. Cutaway view of a controlled air incinerator.

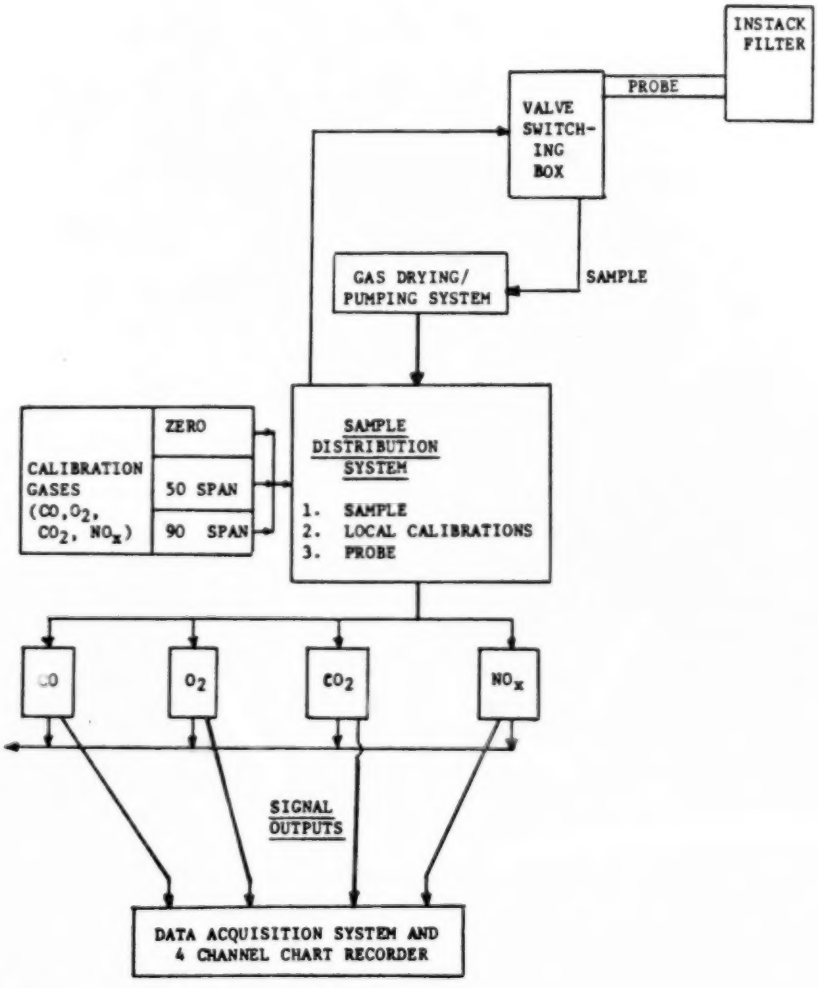

Figure 6. Continuous monitor sampling schematic.

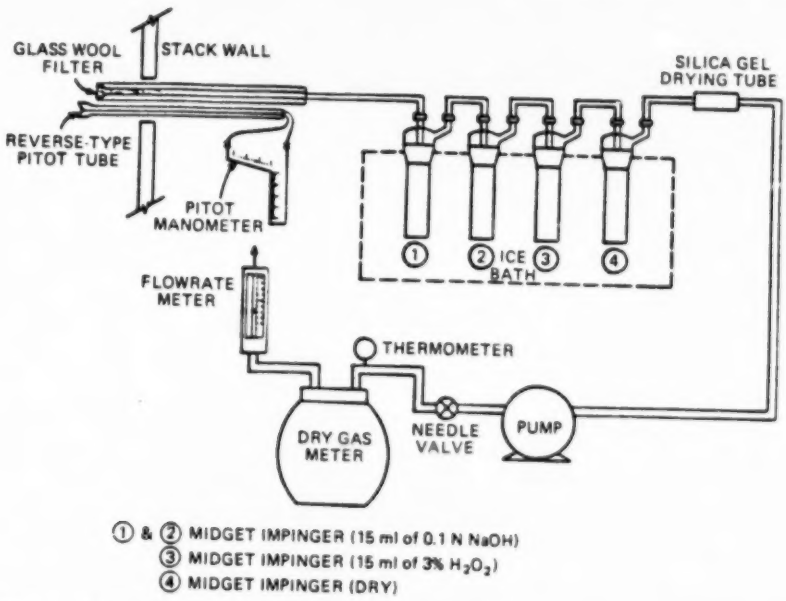

Figure 7. Schematic diagram of hydrogen chloride sampling train.

lates, semivolatiles, polychlorinated biphenyls, and polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/PCDF). A schematic of the MM5 sampling train is shown in Figure 9.

The sample train consists of a glass-lined heat-traced probe with a stainless steel button-hook nozzle and attached thermocouple and pitot tube. After the probe, the gas passes through a heated glass fiber filter. Downstream of the heated filter, the sample gas passes through a water-cooled module, then through a sorbent module containing approximately 25 g of XAD-2 resin. The XAD module, which is kept at a temperature below 20°C, is followed by a series of four impingers. The first impinger, acting as a condensate reservoir connected to the outlet of the XAD module, is modified with a short stem so that the sample gas does not bubble through the collected condensate. The first and third impingers are empty, the second contains 100 mL of deionized water, and the fourth contains a known weight of silica gel. All connections within the train are glass or Teflon, no sealant greases are used. The impingers are followed by a pump, dry gas meter, and a calibrated orifice meter.

The gas samples taken by VOST or MM5 are then analyzed by GC or GC/MS for the organic compounds of interest, depending on the desired specificity. Using the resulting data, the destruction and removal efficiencies can then be calculated.

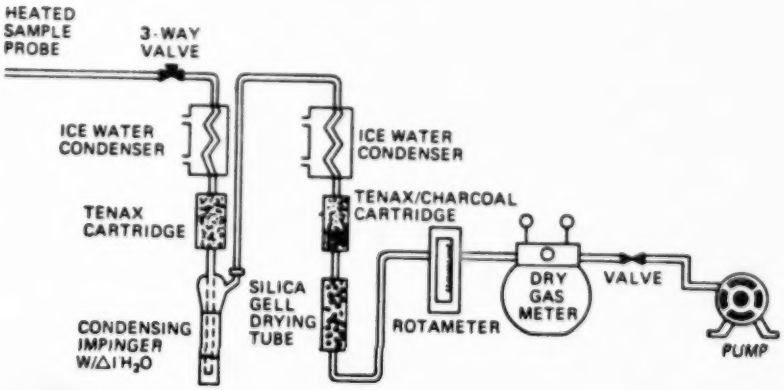

Figure 8. Volatile organic sampling train schematic.

Permitting

Permitting is one of the very important steps in managing an incinerator facility. It can take a minimum of 18 months to obtain the RCRA permit. In addition to the RCRA permit, other permits may need to be obtained as well. The list shown in Table IV is an example of the permit requirements for a recent project within the State of New Jersey.[19]

Conclusion

Incineration is thus far the best demonstrated available technology for waste destruction. Unfortunately, it is not a perfect technology. It may emit unwanted products of incomplete combustion or trace metals. The PICs could conceivably be equally or more hazardous than the original compounds in the waste fed to the unit. However, the amounts of the PICs in the exhaust are generally at least two orders of magnitude less than the original compounds in the feed. Both PIC and trace metal emissions are *very* complicated problems. A considerable amount of research needs to be done in order to ensure that they can be adequately controlled.

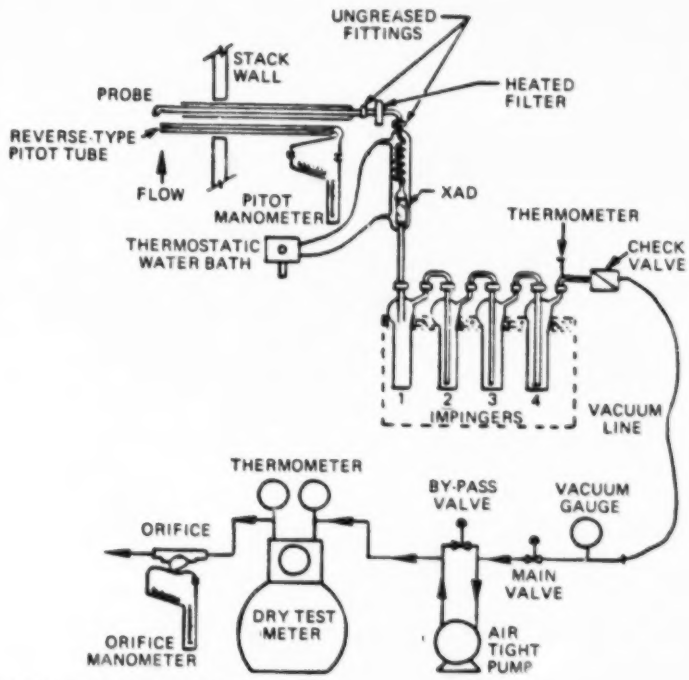

Figure 9. Modified Method 5 train.

Notice. This paper has been reviewed by the Hazardous Waste Engineering Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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This paper was submitted for peer review May 7, 1986; the revised manuscript was received June 23, 1986.